



Weather reforecasting and statistical post-processing as drivers for reanalysis

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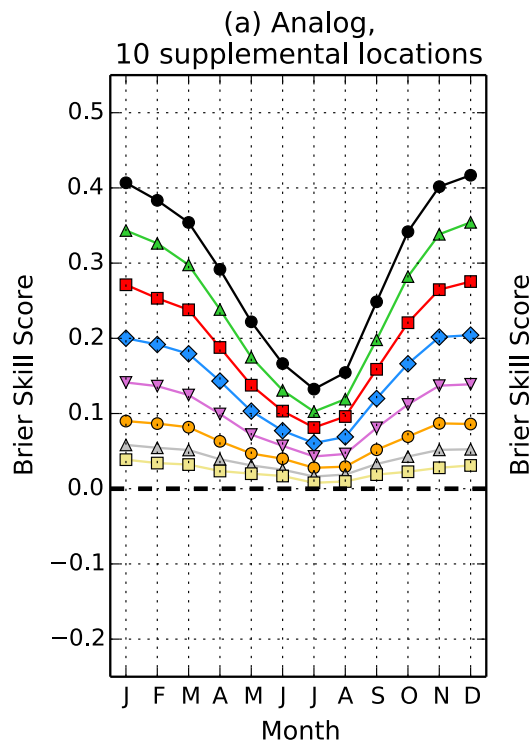
Statistical post-processing

- Given forecasts with biases and random errors, we seek to statistically adjust the real-time forecast using discrepancies between past forecasts and observations/analyses.
- Making useful adjustments are particularly challenging with:
 - forecasts with inherently low skill (e.g., longer-lead forecasts)
 - signal-to-noise ratio is small, so lots of samples needed to extract usable signal.
 - errors at extended leads are typically correlated at large scales, making it less appropriate to correct using supplemental data from other nearby stations.
 - forecasts of rare events.

Benefits from reforecasting

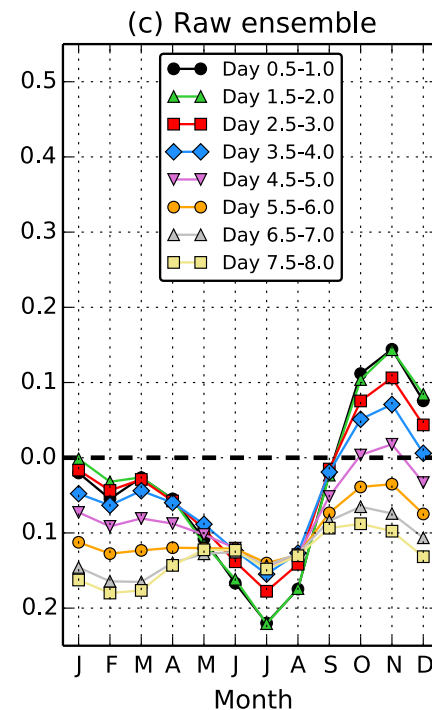
- Reforecasts: **retrospective forecasts**, ideally using same analysis and forecast system run operationally.
- Extra training sample size from large reforecast database (and associated observations/analyses) can greatly improve skill and reliability of statistically post-processed guidance.
- 1985-2014 GEFS reforecasts for currently operational GEFS now available & used here.

Brier skill scores, > q95



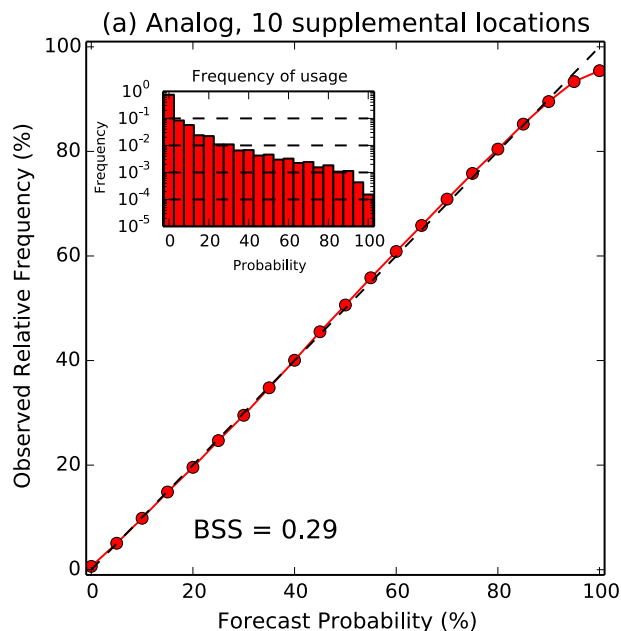
Note the dramatic effect of post-processing, here using GEFS reforecasts, rank analog approach (Hamill and Whitaker 2006) and 2002-2013 1/8-degree CCPA precipitation analyses over CONUS.

Raw ensemble skill is low because of systematic errors, under-spread, and limited ensemble size.

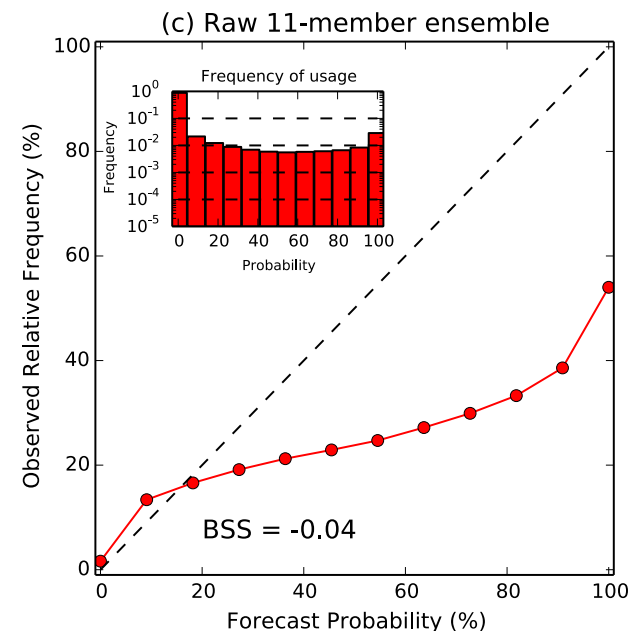


Reliability after (and before) post-processing

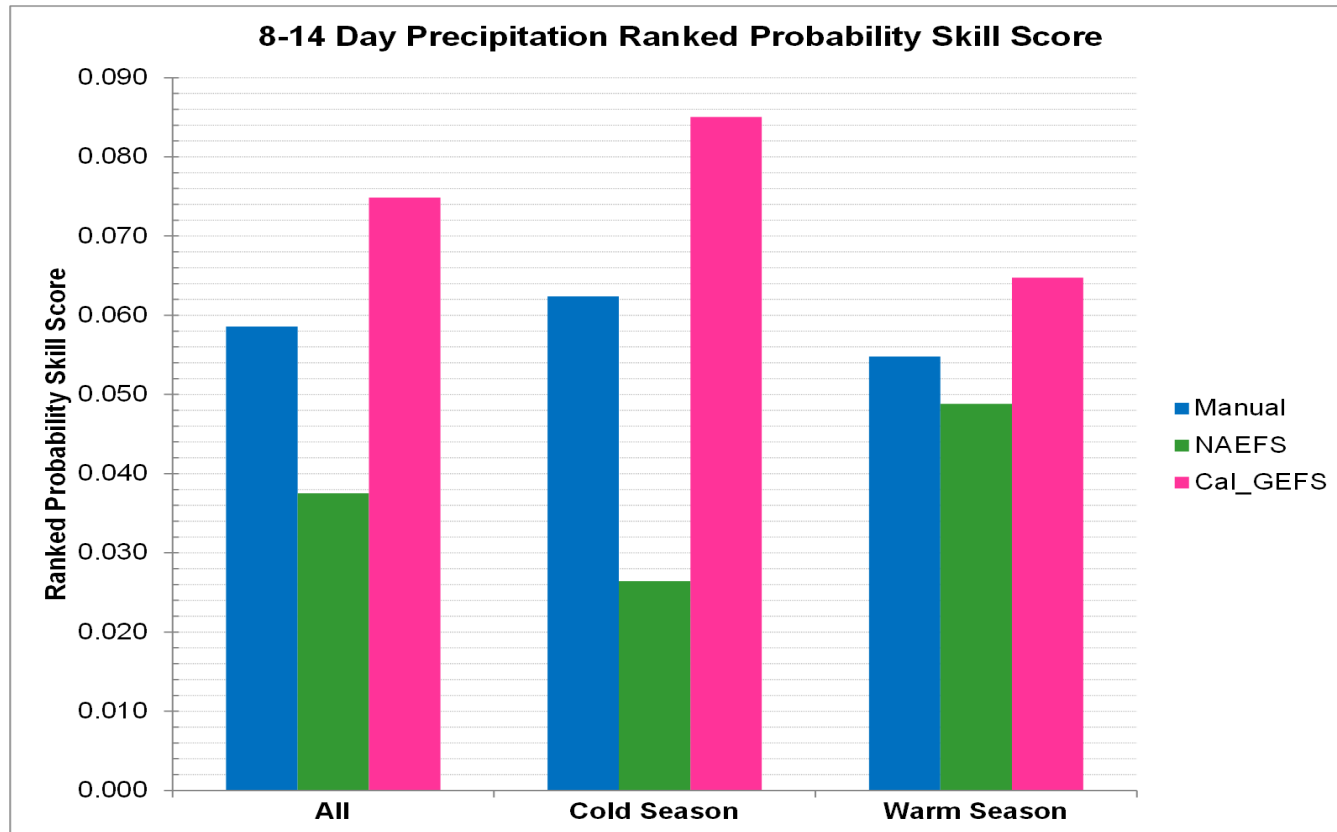
Reliability for 012-024-h, > q95



Statistical reliability can also
be dramatically improved
relative to raw ensemble
guidance.



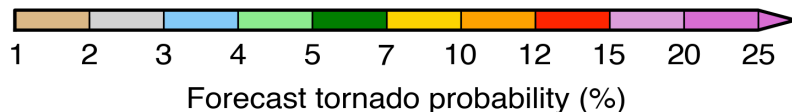
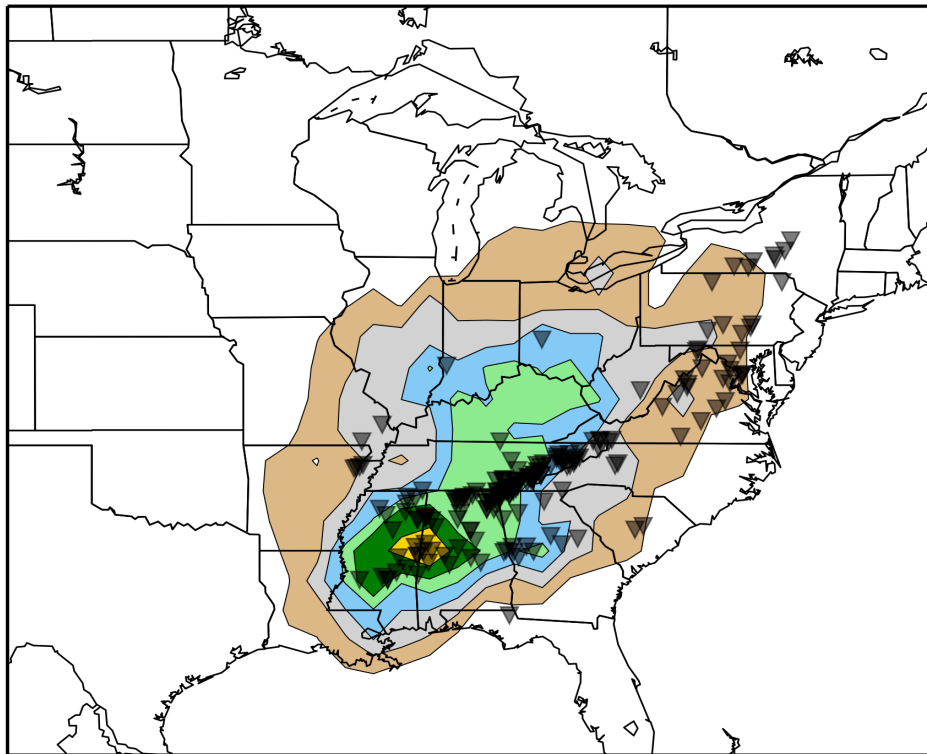
CPC reforecast skill vs. NAEFS, manual



Skill of NCEP/CPC's forecasts of above/near/below-normal precipitation for the 8-14 day period from various methods, including manual forecasts, from NAEFS, and from the reforecast-calibrated GEFS.

Lengthy reforecasts helpful for objective calibration of rare events (here, tornado forecasts)

(a) Tornado Probabilities (F1+), Remapped to 80 km ROI
2011-04-27 12:00:00 to 2011-04-28 12:00:00 UTC
Initialization time = 2011-04-21 00:00:00 UTC



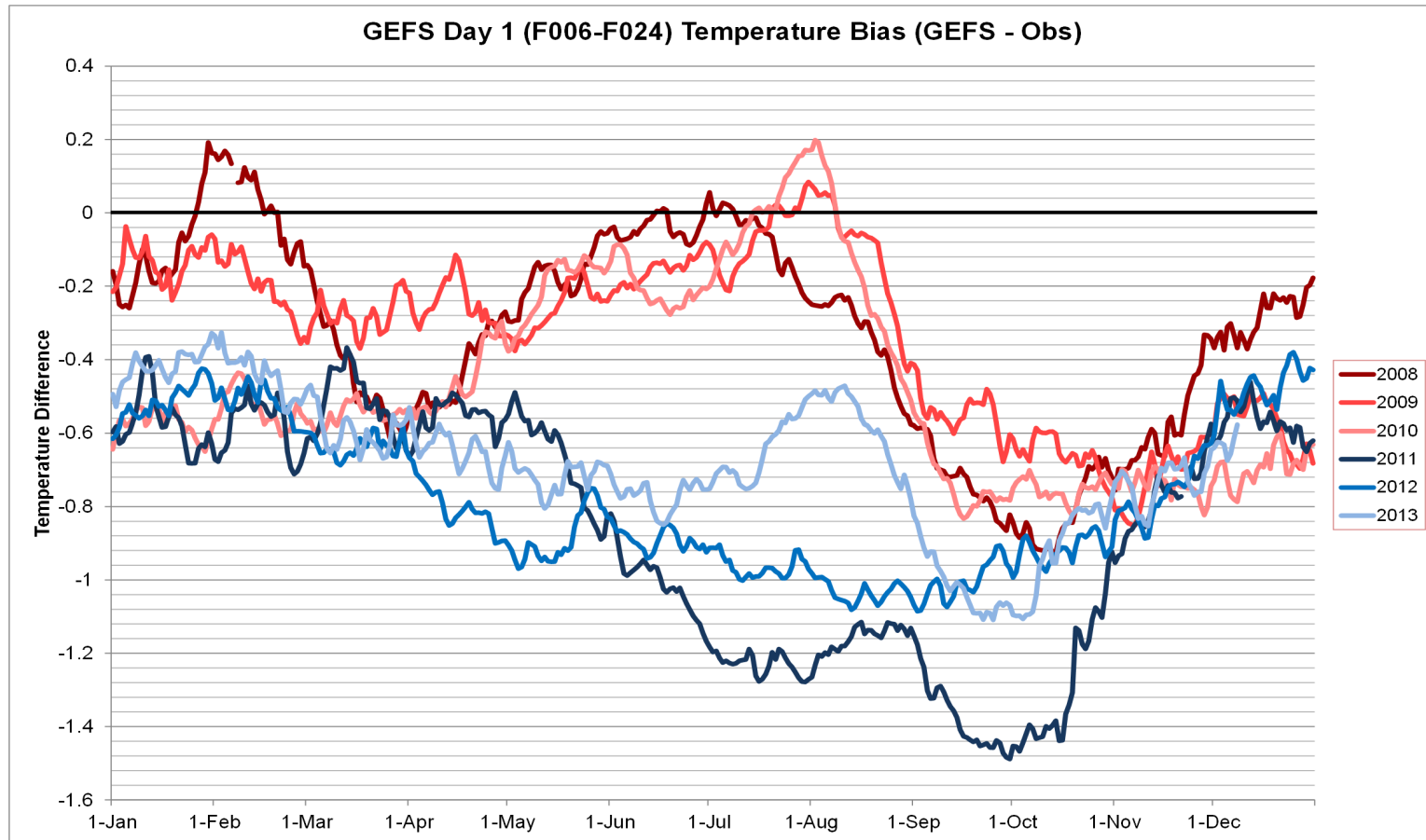
Objective tornado probabilities for the period 12 UTC 27 April 2011 to 12 UTC 28 April 2011 for forecasts initialized 6 days earlier, based on a reforecast analog procedure (Tuscaloosa outbreak). Observed tornado locations are shown with the grey inverted triangles.

c/o Francisco Alvarez, from his Ph.D. dissertation at St. Louis University.

Issues in the computation of reforecasts

- Computational expense.
- Archival expense.
- Need coincident, high-quality verification or analysis data to get the most from reforecasts.
 - precipitation analyses.
 - surface analyses.
- **Necessity of a *consistent* system for initialization and forecast.**

Changing short-term forecast bias due to changes in data assimilation system

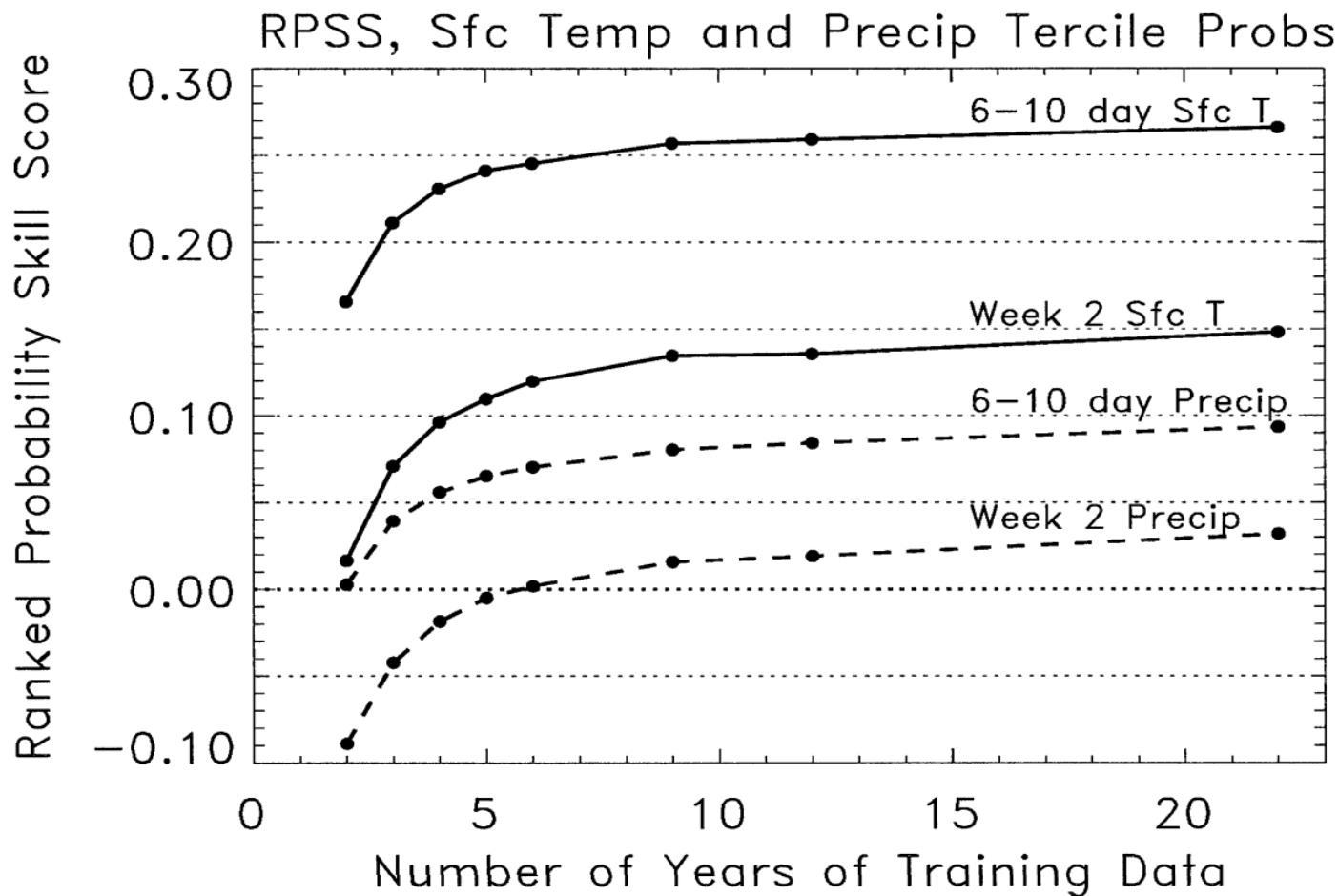


c/o Mike Charles, CPC. In 2011, the reforecasts changed from CFSR initialization to GSI initialization, which used a slightly different version of the forecast model.

Before discussing reanalyses:

can we make the computational
expense of reforecasting
more reasonable?

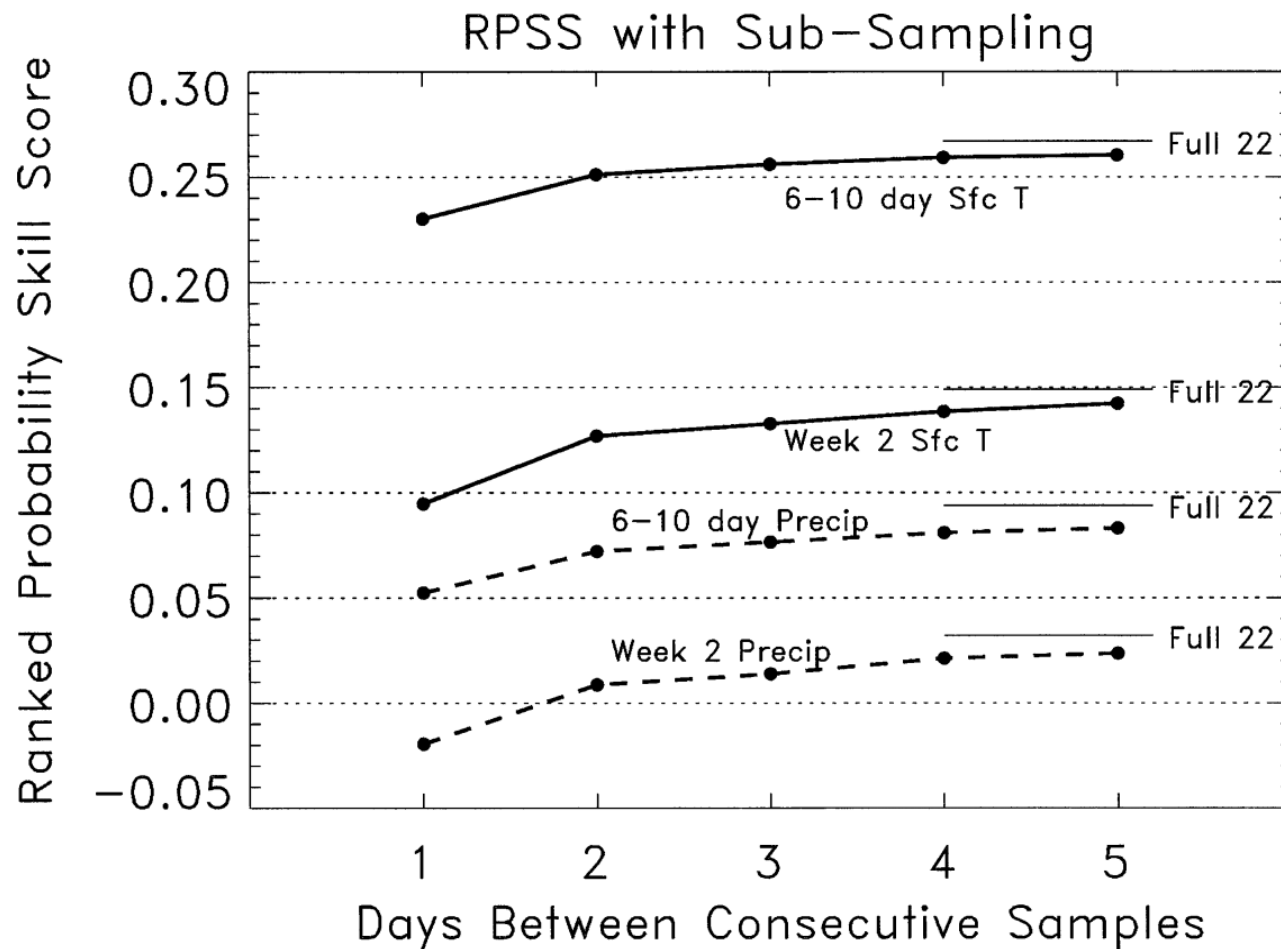
Some sample-size sensitivity results: 6-10 and 8-14 day forecasts.



Ranked probability skill score (larger is better) of post-processed surface temperature and precipitation forecasts as a function of the number of years of training data, assuming every-day samples were available.

(used 1st-generation GEFS reforecasts)

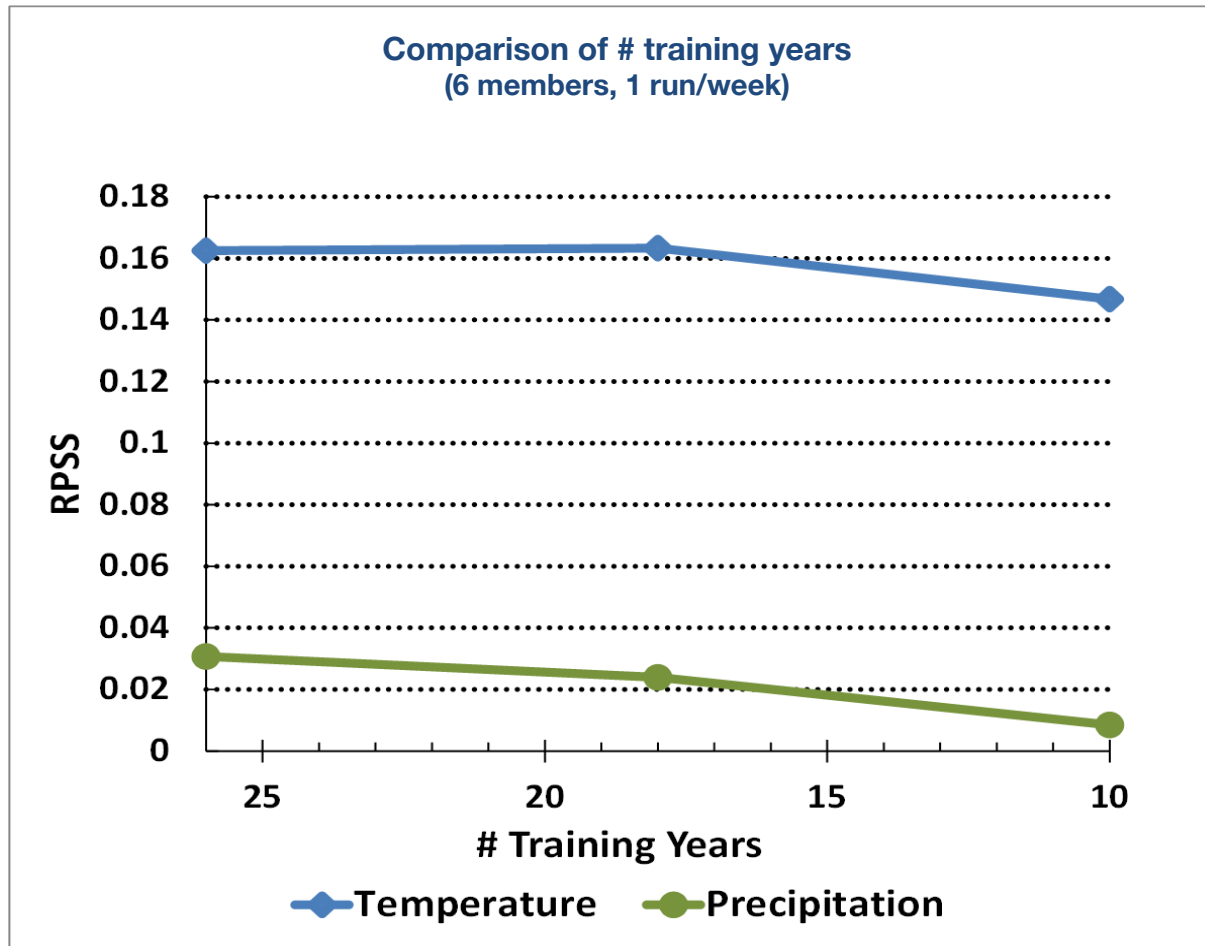
Some sample-size sensitivity results: 6-10 and 8-14 day forecasts.



Ranked probability skill score (larger is better) of post-processed surface temperature and precipitation forecasts as a function of the number of days skipped between forecast samples. In all experiments, four total years of training data were used.

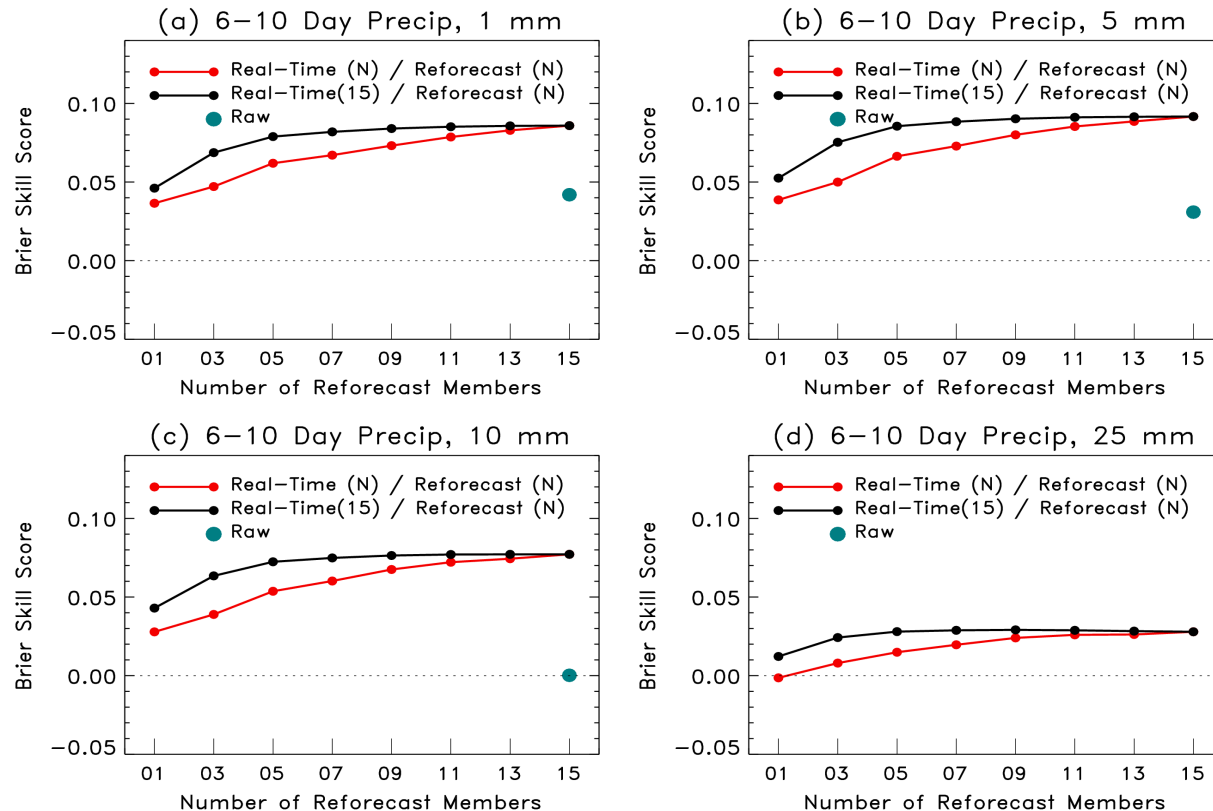
Sample-size sensitivity:

CPC 8-14 day temperature & precipitation



Ranked probability skill score (larger is better) for CPC 8-14 day surface temperature and precipitation skill as a function of the number of years of training data, using GEFS second-generation reforecasts and station observations over the US.

Sensitivity to the number of reforecast members



6-10 day precipitation forecast Brier Skill Score (larger is better) as a function of the number of reforecast members and the number of real-time members. The green dot shows the skill of the raw ensemble forecast guidance, here with 15 members used to set the probabilities. The red curves show the skill when n members are used both as the ensemble size for the reforecast ensemble and for the real-time ensemble. The black curve shows the skill when a n -member ensemble is used for the reforecast and a 15-member ensemble is used for the real-time forecast. ECMWF reforecasts used here.

Recommendations on reforecasting from recent white paper

Recommendation 1

- Until a next-generation reanalysis and reforecast in place and ready for utilization, **NCEP/EMC should continue the production of an 11-member GEFS ensemble for the 00 UTC cycle in its current (circa 2012) configuration.** These real-time forecasts will be approximately consistent with the GEFS reforecast, so existing products can continue to be generated from them. Given the next-generation GEFS will be higher in resolution, this will be a minor computational expense.
 - Computational expense of retaining 11-member GEFS after next implementation? Approximately 4 percent of the cost of the anticipated 84-member (21 x 4 cycles) T574 GEFS.

Recommendation 3

- NOAA should prepare to conduct a reforecast using the anticipated operational configuration of the GEFS. We recommend the following configuration for a GEFS reforecast: 20 years, once every 5 days, with 5 members, and twice daily, from the 00 and 12 UTC cycle. This would be an extra 200 members computed every 5 days, compared with the operational $21 \times 4 \times 5 = 420$ members computed in those 5 days, i.e., an extra ~50% computational expense.

Recommendation 5

- Given the requirements for NDFD guidance of surface weather elements at high (2.5-km) resolution, NCEP should devote the necessary resources to generate a **high-quality retrospective analysis of surface weather with its Real-Time Mesoscale Analysis System.**

Recommendation 2

- NOAA should immediately **begin preparations for the production of a next-generation reanalysis** to support the reforecast generation process, as well as to facilitate other applications inside and outside of NOAA. **The reanalysis configuration should match the operational data assimilation configuration as much as possible.** The necessary preparations include determining the computational, storage, and personnel resources needed, as well as organizing the observational data that will be assimilated. The configuration details of the data assimilation system to be used in the reforecast should be decided in consultations between relevant NWS and OAR scientists. We assume that a future reanalysis will be ensemble-based, providing a number of initial analyses suitable for ensemble reforecast initialization.

Jump-starting production of a next-generation reanalysis

- Operational analysis soon to be 4D-En-Var. Where do we get the computational cycles needed to do 4D-En-Var reanalyses?
 - Steve Lord (NWS/OST) has suggested the possibility of extending the life of existing WCOSS supercomputers after next-generation supercomputers are installed. This may be affordable.
- Where do we get the personnel funding? Probably ~ 9 FTEs.
 - Could we split costs between several programs, e.g., new R2O initiative for production, OAR/CPO for ongoing research, EMC, external users of reanalysis products?
- More regular reanalysis program needed; retain infrastructure after one reanalysis created, learn from deficiencies of that reanalysis, incorporate improved methods into the next.
- Different reanalyses needed for weather and climate. But work together.

Conclusions

- Reanalyses needed for weather (and climate) reforecast initialization.
- Philosophically speaking:
 - *Post-processing and reanalysis/reforecast production need to be thought of as integral parts of the NWP process.*
 - NOAA should give the same attention to detail to reanalysis development and post-processing that they give to development of dynamical cores, assimilation methods, parameterizations, ensemble systems.
- Associated white paper (DRAFT) available at <http://www.esrl.noaa.gov/psd/people/tom.hamill/White-paper-reforecast-configuration.pdf>